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Manufacturing Software for Shipyards

VB-2

Charles Zigelman, Visitor, National Steel and Shipbuilding Co.

ABSTRACT

shipbuilders (or any manufacturers, for that matter) are confronted with hundreds of choices of computer software for controlling manufacturing in today's market. The software, however can, be differentiated by certain salient features or assumptions which may or may not work in the shipbuilding environment. This paper will explore, in general terms, how shipbuilding is different (or the same) from other manufacturers in ways that are significant for the selection of these manufacturing computer systems. Some of the issues to be discussed are master scheduling, configuration management and project based production and inventory control.

INTRODUCTION

For 30 years, manufacturing companies have been using increasingly sophisticated computer software to control production.[1] This type of software, which is known in general as Manufacturing Resource Planning[1] (MRPII), is used to control the manufacturing process by controlling the material that goes into it. Over the years, software vendors have increased the sophistication of their product to match the improvements demanded by the market. These changes have in turn increased the range of manufacturers that have successfully implemented the product. The most notable in recent years have been a growing number of Aerospace and Defense (A&D) users. As shipyards struggle for a competitive edge, they are turning to the solutions successfully implemented in other industries. MRPII can be viewed as a simulation of the manufacturing process. To be useful it needs accurate data processed by a model that matches the real process. Though features and functions may be different, the MRPII model is now remarkably consistent across most software packages. The only major differences are between Aerospace and Defense and commercial business packages.

It is not the purpose of this paper to go into the details of the software selection process. There are already many excellent papers on the subject.[2] Rather, the purpose is *to* explore how well some of the assumptions in the MRPII model fit shipbuilding. The fit of these assumptions is much more important in the long run than the color of the screen, or how many keystrokes it takes to enter a transaction.

SOFTWARE SYSTEM BASICS

To understand the model, let us first explore the basics of how the MRPII software system works.

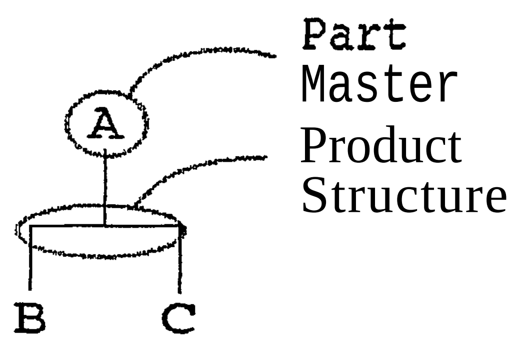

FIGURE 1

SINGLE LEVEL BILL OF MATERIAL

1 In the late sixties, the software only balanced supply and demand for material and so was known as Material Requirements Planning. The systems available *today do* this and much more. They are commonly called Manufacturing Resource Planning systems or NRPII.

At the heart of the system is a bill of material. This bill is a hierarchical model of how a product goes together. It is made up of two major elements: part masters and product structure.

Part masters are the building blocks. They contain the attributes (characteristics) of an item that are common across all of its uses. Examples of these are part number, description, manufacturing or purchasing lead-time, weight, and group technology code. Product structure data shows how the part masters are linked together to make a particular product (Fig 1) Data usually included here is identification of the parent part number, the child or component part number and the quantity of the child needed to make one parent. Depending on the software system selected, these bills can have a virtually unlimited number of levels and constituent parts. At the top of the bill is usually the end product of the manufacturing process.

Once the bill of material has been defined, it can be used to plan and schedule work. This is done by introducing an order for the item at the top of the bill of material. This order is generally developed through a process known as Master Scheduling, in which the company decides, based on forecasts or actual customer orders, just how many of the end items it wants to build and when. Once the order is introduced, the system goes through the "netting and explosion" process. First, the system checks to see if there is any inventory for the item, either currently on-hand, or on order. Then this supply information is compared with the quantity and schedule of the demand. If it is sufficient, the process stops: if not, the system plans additional supply, either a shop order or purchase requisition. The quantity for the order is governed by lot sizing rules captured in the part master data. The schedule for the order is set by backscheduling from the due date using the lead times in the part master.

If the order is for an item manufactured in-house, the system "explodes" the bill to determine the material needed to complete the shop order. The explosion consists of reading the next level down in the bill to determine the list of components. These items are included on the order as the material list with a pick date backscheduled to support the manufacturing lead-time of the parent. The system then applies this new schedule and quantity information as additional demand for each of the components. This demand is in turn checked against any supply information for the components. In this manner the system walks down each level of the bill of material creating a plan and schedule to meet the demand from the level above.

Software vendors usually sell their MRPII systems as a series of integrated sub-systems or modules. Once the orders are created by the planning modules their execution can be controlled by other sub-systems. There is a shop floor control subsystem to control the manufacturing orders through each of their workcenters. The purchasing subsystem is used to manage the conversion of the purchase requisition into purchase orders. A capacity management subsystem compares the plan to the capacity available at the workcenters. The last major piece is an inventory control subsystem used to manage the receipt and storage of inventory. Each subsystem or module is interdependent on the data from the other.[3](Fig 2)

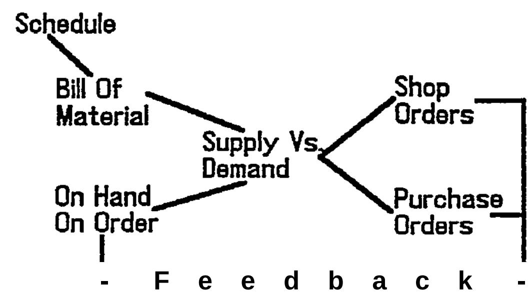

FIGURE 2

CLOSED LOOP SYSTEM

Many manufacturers may already use pieces of the MRPII model like a stand-alone shop floor control sub-system, or some kind of purchasing sub-system. Typically they don't "talk" to each other very well, so the data in the different sub-systems doesn't match. The key advantage of an MRPII system is that all these subsystems are linked together in a meaningful manner. If the users maintain accurate status of their activities, the MRPII system is capable of rebalancing the manufacturing plan based on updated status. This "closed loop" flow of information is the real strength of the system.[4]

With this simplified explanation in mind, the differences between some of the major underlying assumptions of the generic MRPII system and current shipbuilding practice can be explored.

SCHEDULING

The MRPII backscheduling algorithm is often compared with that of a Critical Path Method (CPM) network schedule. Indeed if the bill is turned

on its side it closely resembles a CPM network. This resemblance breaks down though because of one of the significant assumptions in the MRPII system. In a CPM network predecessor/successor relationship the occurrence of the predecessor event is sufficient to allow any number of successors to occur. In the parent/child MRPII bill relationship, however, there is always a specific quantity relationship built in. It is not sufficient for the child to simply occur; instead, it must exist (or be planned to exist) in sufficient quantity for each of the parents that require it. The assumption embedded in the MRPII system is that every item in the bill is a physical item that can be placed in inventory. In shipbuilding, this works fine for earlier stages of construction which deal with real items like pipe spools or steel sub-assemblies. It does not work as well for events that take place later in the construction cycle like test and activation milestones.

One result is that a ship's bill of material cannot be created down from a single end item representing the completed product. Unlike most manufacturing businesses, shipbuilding is a combination of conventional materials based manufacturing processes and unique project type construction activities like testing and activation of a particular piping sub-system. These construction activities do not fit the MRPII model because they require little or no material and the result cannot be stored in inventory.

The generic MRPII model drives the schedule through an end item representing the finished product. This is done with the support of an MRPII sub-system called Master Scheduling. The alternative emerging in A&D companies with products requiring extensive system testing is to integrate existing CPM network scheduling systems with MRPII. Instead of having a single bill of material to control all production activities, they

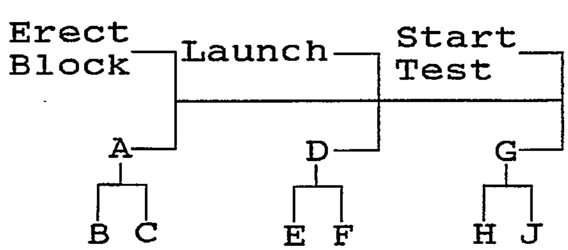

FIGURE 3

INTEGRATED SCHEDULE AND BILL

have many smaller bills each supporting an appropriate schedule milestone that is controlled by the CPM network.[5] The small bills of material control the purchasing, fabrication and assembly of physical interim products. The CPM schedule controls the testing and integration of these interim products into the final product (Fig. 3). Shipbuilders can conclude two things. First do not throw away network scheduling system. Second, do not expect to get much out of the Master Scheduling sub-system of MRPII.

PART NUMBERING

Another assumption in the MRPII system concerns part numbering. In MRPII the part master data lives in a single large file. This file is set up with the assumption that the part identities follow the rules of form, fit and function. These rules as applied are quite simple. They say that items with the same part number are always interchangeable, regardless of the revision level of the drawing that produced them - the "blind mechanics rule." Imagine a bunch of the items piled into a bin. A mechanic should be able to pull items out of the bin blindfolded and still get the right item.

Form, fit, and function are defined relative to the use of the item. Suppose an item is used as a component inside of a box. Since no one can see it, the color is not significant. Items with different colors could have the same part number, provided the qualities that were relevant to the application were identical. On the other hand, the color of components that can be seen is significant for a product that is differentiated by color[6].

Form, fit and function are also applied when an item changes its configuration due to a change of the drawing. If the rules are applied correctly, items that are no longer interchangeable get different part numbers. In other words, if the item defined by the new revision of the drawing is no longer interchangeable with the item defined by the previous revision, the new item must get a new part number. The MRPII system does not distinguish between the new item and the old item other than by part number.

A common mistake shipbuilders make in part numbering is assigning different numbers to items that are identical by form, fit and function. This is sometimes done to distinguish the parent item or shipboard location which an item is assigned. The MRPII system will tolerate this but it causes in-efficient planning. When the system

develops its material plan, it does so part by part. Each part number has its own set of inventory records and supply orders. While many systems have the ability to record group technology codes as part attributes, they are not used directly in developing the material plan. Therefore, it is to the advantage of the system user to assign identical items the same part number. Data about the particular usage of one of these identical items should be stored in the product structure link between that item and a particular parent. For example this data could include the specific compartment location and unique identity assigned to support Navy logistics systems. Unfortunately most generic MRPII software systems do not have enough room in their product structure data file to store all of the information required by shipbuilders.

It is important for shipbuilders to understand another aspect of part numbering. Items that are not the same cannot have the same part number regardless of what contract *or* design they were developed for. Unless the contract or class of the vessel is somehow explicitly included in the part number (making the part number different between different contracts or classes of vessel) the system will assume that items with the same part number are the same. All planning and scheduling will be done with the assumption that the items are physically interchangeable among all sources of demand. This is true of an MRPII system intended for the commercial market. A variant that is important to understand is the system that can do contract specific material planning.

CONTRACT SPECIFIC MATERIAL PLANNING

The standard NRPII system designed for commercial applications assumes that all in-process inventory is owned by the manufacturing company (an over-simplification but true enough for this explanation). Only after the end item is completed and shipped does ownership change hands. This means that not only are parts with the same number physically interchangeable (by form, fit, and function) but they can also be used for any order regardless of the customer which that order ultimately supports.

In shipbuilding, particularly for the Navy, this assumption could land YOU in jail. The Department of Defense, and many commercial shipbuilding customers, requires tracking ownership of the material long before the delivery of the end item. As a result, MRPII systems for the Aerospace and Defense market include the ability to plan by contract. The material plan is prepared in much the same way as previously described with one major addition. The system now keeps track of the contract that caused each demand. Then, based on co-mingling rules defined to it, the system plans specific orders to support specific contracts or groups of contracts. It is important to remember that the form, fit and function rules still apply. The system still assumes that items with the same part number are physically interchangeable. In fact, items which support different contracts may still be stored in the same bin. It still does not matter which one the mechanic pulls out. The difference is that the system knows which contract's inventory to debit.

INVENTORY CONTROL

The MRPII model is based on manufacturing processes with a high degree of product discipline. It assumes that the parent item's identity is derived from the components that go into it. To illustrate how this affects inventory control assume there is a manufacturing order for a single parent item. At the start of the manufacturing cycle for the order there is no parent, just a pile of components waiting to be worked. At the end of the cycle there is the parent and no components; they have all been consumed into the parent. If the components are not all consumed, then the MRPII model considers that a symptom of one of two problems: either the bill of material is wrong, or the parent item specified by the order cannot exist. If the bill of material was accurate, but all the components were not consumed, then the parent cannot exist because its configuration is defined by the sum of all the components, not just the ones that happened to get used. Most commercial and many aerospace manufacturers hold to this assumption in a significant way. If all the components are not consumed, then the parent does not exist. The partially completed product will be delayed until it can be finished.

Compare this MRPII system assumption with shipbuilding practice. Following the National Shipbuilding Research Program (NSRP) terminology, suppose that a block is to have 35 pipe spools installed in it after blast and paint but before block erection.[7] The bill of material representing this plan would show the completed block as the parent and the 35 pipe spools as the components. If only 25 of the spools are actually installed, does the parent item "Block xx" exist? If the answer is yes, it does, a mismatch

exists between shipbuilding practice and the MRPII model.

In most MRPII systems, there are two kinds of places inventory can be: in a stock location available as on-hand inventory, or issued to a manufacturing order that is somewhere in process. Any parts not consumed by an order must be turned back into on-hand inventory to regain available status. If the order is statused as complete, then the system assumes that the real parent is available and interchangeable with any other item with the same part number. There is nothing in the system that automatically considers "This item A is almost the same as that item A, You just have to add on these items that should have been done earlier". There are ways to accomplish this feat. They involve using the change management portions of the MRPII system.

CHANGE MANAGEMENT

Change management for shipbuilding involves many issues beyond the scope of this paper. For most of these issues. the fit of the MRPII model is irrelevant. The exception is how the model handles the incorporation of changes to the bill of material. There are different approaches depending on the type of manufacturing the system is intended to support. On one hand there are make-to-stock consumer oriented manufacturers. They can design, then prototype the manufacture of a new item prior to starting mass production. Once the production line is rolling, there is relatively little change introduced.

On the other hand are design-to-order manufacturers like shipbuilders. A complex one of a kind product is engineered from scratch. The prototype goes into production even before all the engineering is complete. It is not an experiment that can be thrown away, its a customers valuable product. As problems in the design and production plan are revealed during the prototypes construction they must be fixed in a cost and schedule effective manner. These solutions must also be incorporated into any follow ships which are similar but rarely identical.

One way to view the life cycle of any product is to define three different bills through which it transitions: As-Designed, As-Planned, and As-Built. The As-Designed bill is the earliest view showing the engineering version of the content of the product. Typically, there is little or no production information associated with this bill. A good example of this in shipbuilding would be a system diagrammatic.

The engineering view is often not sufficient to plan and control the material needed for manufacturing. The As-Planned bill rearranges the engineering view and adds production information. It includes an interim product breakdown, (which can be quite different from the way the drawing was organized) process and routing, tooling, and identification of additional production material such as jigs and fixtures. A pallet list which identifies all material needed to do the job is an example of an As-Planned bill.

Finally, the As-Built bill records how the product actually went together. This is where actual material identities and amounts used are recorded.

The MRPII systems designed to support design-to-order manufacturers will have the ability to store these different versions of the bill, while the standard systems do not. This gives the opportunity to maintain a drawing based engineering view (As-Designed) separate from a product based manufacturing view (As-Planned).

The As-Planned bill can also have two versions, the Class Plan and the Product Specific Plan. These represent the difference between goals and reality. The Class Plan is the way we would imagine the ship should go together. It assumes a nearly perfect world, where all the engineering is done, the material is all bought and available, the necessary manning and facilities are ready, and relatively little change is being introduced into the bill. One way to envision the Class Plan is to think about how to build the fourth or fifth commercial ship in a class.

Unfortunately after Class Plans are set in motion, the Product Specific Plan is needed to take account for reality on a specific hull. When engineers make changes to their drawings they usually think of the changes as Class Plan changes. That is, the engineers do not consider where in the construction cycle the ship actually may be; they modify the drawing to show how the ideal ship should go together.

The- production plan, on the other hand, must reflect the status of the ship. If more than one ship in a class is under construction for example, a change may be implemented on different interim products for different hulls depending on each hulls status.

There are different ways to handle change in the As-Planned bill, particularly if more than one hull is involved. To understand this difference one more bill type must be introduced, the order bill.

In all MRPII systems, regardless of the type of manufacturing they are designed to support, the material based

production plan is captured as the multilevel As-Planned bill. The execution of the plan is governed by orders, either manufacturing orders or purchase requistitions. These orders are created as a result of the previously described explosion process: the system reads the next level in the bill of material to determine the material list . This data is stored in a separate file and is called the "Order bill."

There are a number of options in the way the system interprets the As-Planned bill to create the content of the order. These options are known as "effectivity rules". Some rules are intended to support the make-to-stock environment, some the design-to-order. Different MRPII systems will have different sets of rules embedded in them depending on the type of manufacturing they are intended to support.

The simplest rule is "What you see is what you get." It means what it says; the content of the Order bill equals the content of the As-Planned bill at the moment of explosion. If something is added to or deleted from the As-Planned bill after explosion, there is no way to tell what the difference is other than by a line by line comparison of the old bill to the new.

A refined method of controlling effectivity is by date (Fig. 4). This means that items added to or deleted from the As-Planned bill have an "effectivity date" associated with them.

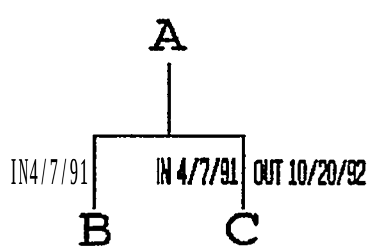

FIGURE 4

DATE EFFECTIVE BILL

This date indicates when the change should be included in the explosion process. It allows currently effective segments of the As-Planned bill to coexist with other segments that are not yet ready to be used. The system compares the date when the order will be used with the effectivity dates of the As-Planned bill and reads only those segments that should be included. A user can inquire into the As-Planned bill and see the old and new views simultaneously to understand the magnitude of any change. Each change in the MRPII system must be associated with a specific change authority before it can be entered. The change authority is the number of the document that authorized the change like an Engineering Change Notice (ECN). Since a change authority is associated with each bill revision the user can trace each bill change to the piece of paper that authorized it.

The problem with date effective bills in the shipbuilding environment is that it can be difficult to manage the dates. In the make-to-stock environment it is relatively easy to pick a date when a change should take place. Then the change is cut in simultaneously for all products in process on that date. In shipbuilding the change may take place on different dates for different hulls depending on a number of factors like material availability and fit with the production plan. Even more difficult to manage is changing the date in response to schedule changes. Shipbuilders, along with many design-to-order users tend to think in terms of the end item for which the change is effective; not a particular date. In other words, shipbuilders may say, "For Hull A we'll do it prior to launch, but for Hull B we'll do it after." This way the user does not have to specify in advance the date that a change will be effective, only the interim product that will change. This technique is known as end item/serial effectivity (for the "serial number" of the end item, like hull 100, Fig. 5). When the order is created, the system knows the end item or hull that it is for and chooses the segments of the bill accordingly.

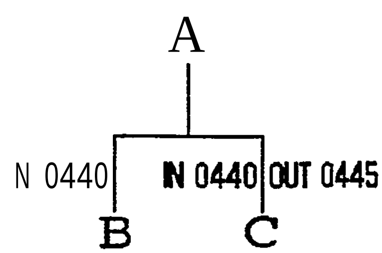

FIGURE 5

END ITEM EFFECTIVE BILL

This effectivity method also has a change authority associated with it.

CONCLUSION

Shipbuilding is manufacturing. It may be different but it is not so

different that it cannot take advantage of modern materials based manufacturing software.[8]

Manufacturers confronting the decision whether to use any packaged MRPII software usually have two alternatives. One is to continue to use the hodgepodge of homegrown software systems that have grown up in the company over the years. The users in each area of the company have grown quite comfortable with "their" system. Unfortunately "their" system either doesn't talk to anyone else's or has redundant but slightly different data than the other company systems. Either of these possibilities makes the efficient interchange of information across organizational boundaries difficult.

The other choice is to attempt to design and program a software system from scratch. This choice is prohibitively expensive for a system of the size and complexity of a modern MRPII system.

No packaged software system will match shipbuilders or any other manufacturers requirements perfectly. A company gives away a perfect match to the needs of any of its individual pieces. It gets in return an integration that helps tie together all the pieces. This integration, built around a well tested model incorporating good manufacturing practices, is an important competitive edge for American shipbuilders.

REFERENCES

1. James P. Gilbert, Richard J. Schonberger, "Inventory-Based Production Control Systems: A Historical Analysis", Production and Inventory Management, Vol. 24, No. 2, APICS, Falls Church VA, 1983.

2. George J. Miller, "Software Selection - One More Time!", 28th Annual International Conference Proceedings, APICS, Falls Church VA, 1985.

3. T.E. Vollmann, W.L. Berry, D.C. Whybark, Manufacturing Planning and Control Systems, Second Edition, Homewood, IL, Dow Jones-Irwin, 1988.

4. Joseph Orlicky, Material Requirements Planning: The New Way of Life in Production and Inventory Management, New York, McGraw-Hill Book Company, 1975.

5. Ronald N. Sullivan, "The Network Schedule and the MRP II Master Schedule", APICS 1988 A&D Symposium Proceedings, APICS, Falls Church, VA, 1988

6. Dave Garwood, Bills of Material: Structured for Excellence, Marietta GA, Dogwood Publishing Company Inc., 1988.

7. R.L. Storch, C.P. Hannon, H.M. Bunch, Ship Production, Centreville MD, Cornell Maritime Press, 1988.

a. P.C. Powell, C.I. Zigelman, "Formal Manufacturing Approaches to Modern Shipbuilding", Journal of Ship Production, Vol. 4, No. 3, August 1989.

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